

STUDY ON THE UPGRADING OF CHINA INTEGRATED CIRCUIT (IC) INDUSTRY UP TO THE GLOBAL VALUE CHAIN: A CASE STUDY¹

Liu PingQing² Gao Yonghui³ Gu Qiang⁴

Abstract: In the globalization era, cost competitiveness alone will not be sufficient to guarantee further success. The China's Local Industrial Clusters (LICs) faced a serious challenge between the top-down (global) and bottom-up (local) governance pressures. This paper uses the Global Value Chain(GVC) framework analysis to explain China Integrated Circuit (IC) industry's development stage, position of the GVC, and demonstrate that the relationships with these global actors and upgrading opportunities of IC.

Key words: Local Industrial Clusters (LICs), Global Value Chain (GVC), Governance, Upgrading Risk

1. IC INDUSTRY: A DEFINITION

IC, sometimes called chip or microchip, is a semiconductor wafer on which thousands or millions of tiny resistors, capacitors, and transistors are fabricated. The IC industry emerged in the late 1950s in the U.S., took form in the 1960s, and experienced rapid growth in the 1970s. The global IC industry has undergone tremendous changes in the past decades. The rapid rate of innovation in the semiconductor industry facilitated the information technology revolution, which in turn has spurred rapid expansion in all sectors of the economy all over the world. 2005, the worldwide IC revenues amount to \$210 billion. From 2006 through 2009, IC market continued growth to \$330 billion⁵. As of 2005, the top 10 semiconductor companies⁶ worldwide based on sales, ranked starting with the largest were Intel, Samsung, Renesas (Hitachi-Mitsubishi merger), Texas Instruments, Toshiba, Infineon, STMicroelectronics, NEC, Freescale and Philips.

¹ This work was funded by the National Natural Science Foundation of China(70503003), Beijing Excellent Talents Fund(20071D1600300395) and Excellent Young Scholars Research Fund of Beijing Institute of Technology(00Y08-33).

² School of Management & Economics, Beijing Institute of Technology, 5 South Zhongguancun Street, Haidian District Beijing 100081, China.

E-mail: liupingqing@bit.edu.cn

³ School of Management, China University of Mining & Technology, Beijing, 100083, China.

⁴ Department of Small and Medium-sized Enterprises, National Development and Reform Commission, Beijing, 100053, China.

⁵ IC insight, 2006 IC economics report, <http://www.electronics.ca/semiconductor>.

⁶ Original data provided by iSuppli in November 2005,

<http://www.geek.com/news/geeknews/2005Dec/bch20051202033584.htm>

* Received 11 July 2007; accepted 23 August 2007

The reorganization of global IC production from a vertically-integrated, geographically-concentrated, closed system to a vertically-disintegrated, geographically-dispersed, open system forces the “flagship” companies in the global production system to share their knowledge more aggressively with distant network partners as they are under constant pressure to deliver the products faster and at lower costs (Ernst, 2002). Of course, manufacturing continues to move toward lower-cost regions of the world, and away from developed regions. For example, in the U.S. domestic manufacturing capacity has fallen from a high of 28 percent in 1999 to less than 25 percent in 2005, with a particularly steep drop in leading-edge capacity to 14 percent in 2005⁷. This provides opportunities for developing country producers to leverage their knowledge and capacity with those in developed country.

2. CHINA’S IC INDUSTRY AND IC LIC

As part of China's national independent innovation strategy to develop the IC industry, as well as the recognition of the importance of IC design, both the Chinese government and the IC community are working fast to develop the IC and related industries. Chinese government has always been supporting strongly the IC design industry and has released a series of preferential measures to encourage the development of IC design houses, including Document No.18 and Document No. 51, tax refund, and discount government loan, when setting up specialized industrial base and supporting IC firms.

According to China Semiconductor Industry Association (CSIA), by the end of 2004, China had about 50 foundries, 102 testing and packing factories, and 457 design firms. By the end of 2005, China's IC design houses totaled at 479. Actions Semiconductor and Vimicro Corporation, two design firms, were successfully listed on NASDAQ. Foundries in China generally fall into four categories: investment by oversea Chinese with co-investment from the Chinese local government (e.g. SMIC); Sino-foreign joint-ventures, such as Huahong-NEC; Subsidiaries of Taiwan foundries or direct investment by the Taiwanese foundries; and Chinese domestic investment. Indigenous OEM vendors are also moving into the semiconductor sector, Huawei, ZTE Telecom, and Hisense all set up independent subsidiaries focusing on semiconductor product development. Lenovo, China’s largest computer manufacturer also released its computer security chip, becoming the 5th manufacture with proprietary security chips. In the past 5 years, the annual growth rate of domestic IC industry has exceeded 30%. In 2000, the IC output amounted to 3.39 billion pieces, and achieved 25.58 billion pieces in 2005 (table 2). The mainstream process technology also had decreased to 0.18 um⁸ of 2005 from 0.5 um of 2001. Sales revenue from China’s IC industry is expected to be \$2.06 billion in 2006.

Table 2. China’s IC Production and Import from 2000-2005⁹

	2000	2001	2002	2003	2004	2005
Output	3.39	3.32	9.63	12.41	21.15	25.58
Growth rate	38	-2.0	189.3	28.85	70.4	25.68
Import	20.6	20.0	26.1	46.9	62.8	75.4
Growth rate	18.8	-2.4	30.1	79.7	33.9	20.0

China has a large and fast growing IC market. IC Insight data shows that in 2005, Chinese IC market reached \$40.8 billion (Chart 2), which accounted for one-fifth of global total, that is to say, China became the largest IC market. The biggest driver for IC comes from demand for computer related

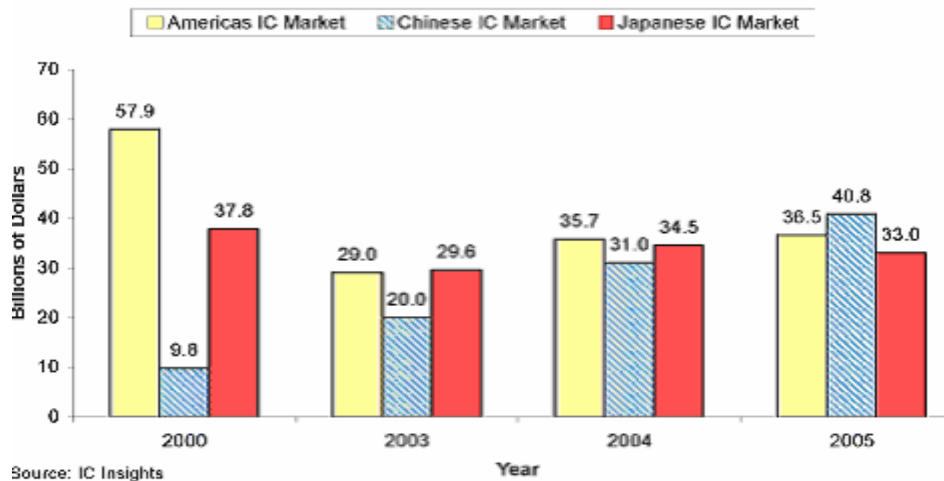
⁷ www.sia-online.org/downloads/SIA_AR_2006.pdf

⁸ it's referred to “micrometer”.

⁹ The output and import unit is billion pieces, the growth rate unit is %, the data from CCID.

products. Due to the greatly improved desktop PC and notebook production capability of Chinese companies, computers are still the largest semiconductor application area with a share of 39.5% in the IC market. Market share of semiconductors for consumer electronics remains high and is 13% higher than the global market. Industrial applications are the most diverse out of the five major market segments: computer, communications, automotive, consumer and industrial.

Chart 2 China became the largest IC market



Chinese government has selected Shanghai, Xi'an, Chengdu, Beijing, Wu'Xi, Hangzhou and Shenzhen to set up IC design and manufacture bases. Criteria for selecting these cities included a good IC industry supply chain environment and infrastructure, and better technology bases compared with other cities. In fact, clustering IC firms are in Suzhou, Shenyang and Dalian. These bases are still in the fledgling industry cluster, but not true sense of the industrial cluster. Shanghai Zhangjiang National IC Industry Park initially applied "Industry Chain" development strategy, integrating the resources of Shanghai IC R&D Center and first class microelectronic research institutes in China such as Tsinghua University, Peking University, Fudan University, Shanghai Jiaotong University, etc to create patented products in the field of key technology, key material and key equipment, and put them into business production. More than 200 renowned domestic and overseas enterprises are located at Zhangjiang. The total output of IC of 11.1 billion RMB accounts for half of the total amount in mainland China in 2005, and the production capacity of 8-inch wafer accounts for 70% of the total production capacity of mainland China. Two 12-inch 90nm production lines have put into use in 2005 and 2006 respectively. Other IC design and manufacture bases also maintain high speed growth. Cluster effect has emerged in the IC industry. The Yangtze River Delta has become an important area for the IC industry .

3. GVC ANALYSIS

This paper gives a judgment about Chinese IC industry position of GVC.

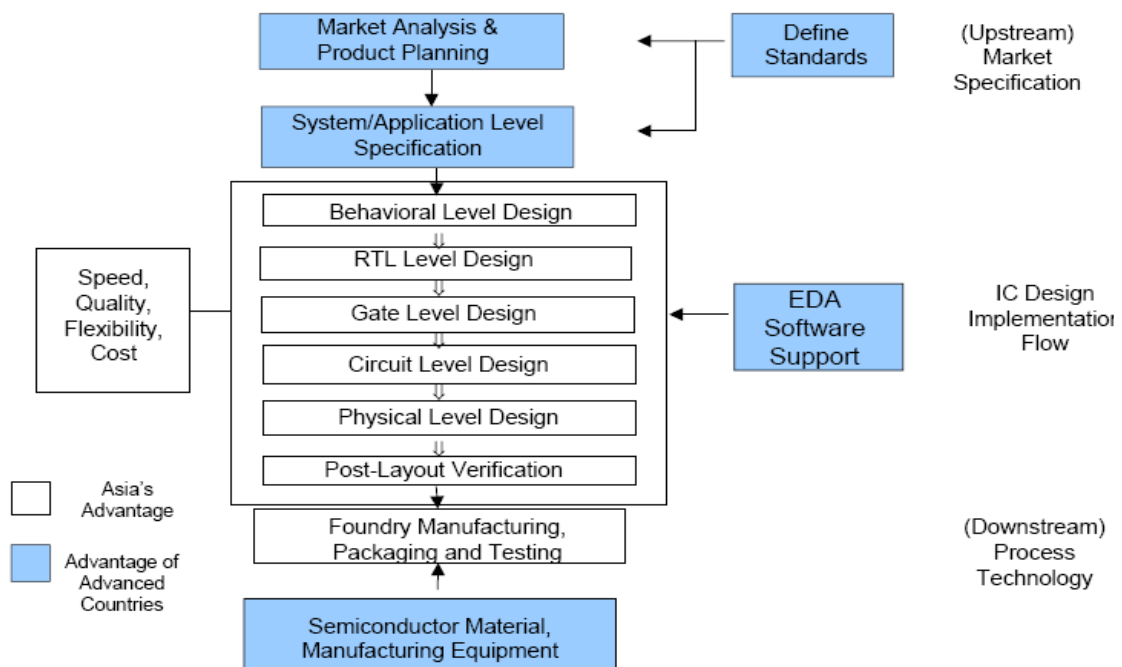
3.1 Governance and rule-making.

Along with the deepening of specialization, some new business models are emerging. There are different business models in IC industry. One is IDM, i.e. Integrated Device Manufacturer, a company that

performs every step of the chip-making process, including design, manufacture, test and packaging. Examples of IDMs are Intel, AMD, Motorola, IBM, TI and Lucent. Another is foundry, i.e. a semiconductor manufacturer that makes chips for third parties. It may be a large chip maker that sells its excess manufacturing capacity or one that makes chips exclusively for other companies. Still another model is Foundry, a semiconductor manufacturer that makes chips for third parties. It may be a large chip maker that sells its excess manufacturing capacity or one that makes chips exclusively for other companies; the third model is Fabless, a semiconductor vendor that does not have in-house manufacturing facilities. Although it designs and tests the chips, it relies on external foundries (fabs) for their actual fabrication. Fab, is a manufacturing plant that makes semiconductor devices. Some companies are mixture all of the models, e.g. Intel is IDM and meanwhile is a Fabless company in certain businesses.

IC industry traditionally is modular governance model, in which suppliers in modular value chains make products or provide services to a customer's specifications; and these suppliers tend to be highly competent, with an ability to provide "turn-key" or "full-package" services. So there are clear signs that contract manufacturing is becoming more global, with leading contract manufacturers providing a global footprint for their customers (Sturgeon and Lester, 2001). Even some new models are emerging; the governance of GVC isn't changing. In the top of IC design flow (chart 3), the system companies define the standards, and decide the application level of specification. These system companies are making the rules (legislative governance) and enforcing the rules (judicial governance), which means all of design and products need to integrate into system companies. It also requires the company to have command over scarce technologies, access to better skills than competitors, and to possess superior forms of internal organization. In fact, there are not many companies which are in this stage in China.

Chart 3 IC Design Flow Chart

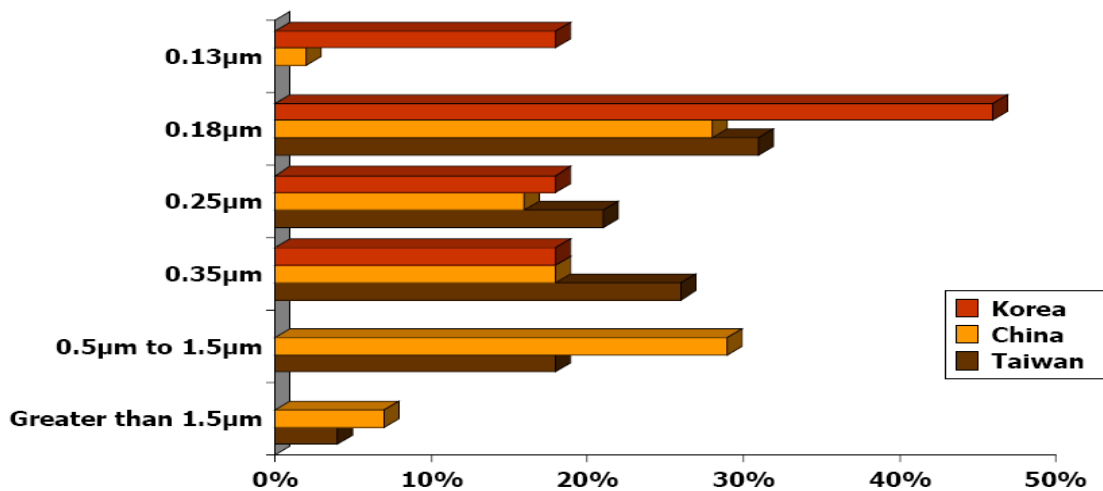


Source: Dieter Ernst, Complexity and Internationalisation of Innovation

3.2 Design

China's IC design has achieved a great progress, but big gap with advanced countries still exists IC Design houses with below $0.25\mu\text{m}$ ¹⁰ line-width (including 0.25, 0.18, $0.13\mu\text{m}$) accounted for 20% in 2001, and the figure rose to 71% in 2005. Many design houses have adopted $0.18\mu\text{m}$ and $0.13\mu\text{m}$ process technology when they design new products. But compared with Korea, Taiwan, China companies still lag behind with under $0.25\mu\text{m}$ line-width level (chart 4). The design capacity of SOC & IP core is far from satisfying domestic market demands; most products have a low-end grade. The development of wafer foundry industry in China is greatly hampered by IC design houses. Among those 500 IC design houses, only at most 50 are able to have mass productions. Over 90% of those companies are just conceptual ones relying on loans or external investments. Even within these 50 design houses which are having mass productions, more than 90% of them focus on logical IC rather than analog IC. China IC design houses are generally medium- and small-sized. There are few large firms with great influence on the industry.

Chart 4 Korea, China mainland and Taiwan IC design capacity comparison



source: www.eetkorea.com, IC design House Survey 2006: Korea

3.3 Manufacture

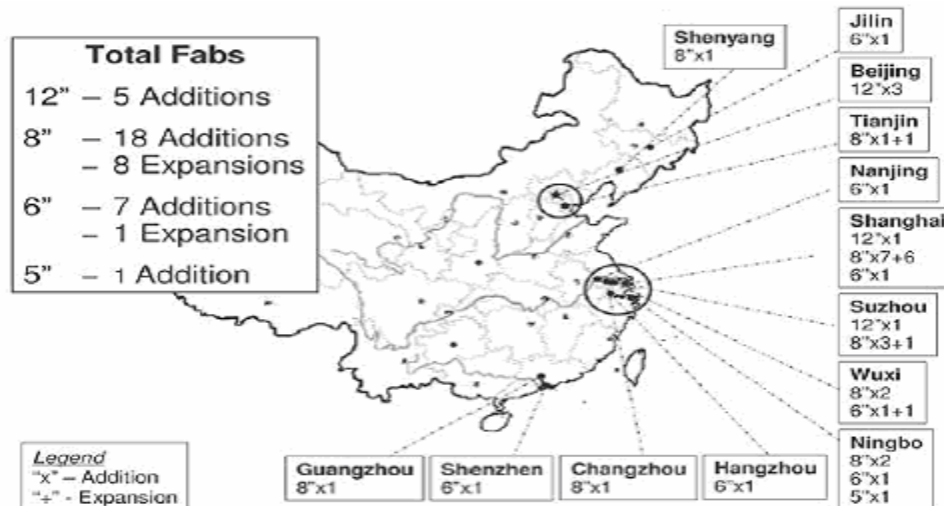
In IC process technology, China lags behind the U.S., South Korea, Japan and Taiwan. Traditionally, the IC industry concentrated in the US, Japan and Europe with big companies doing vertical intergration. At 2006 top 15 worldwide semiconductor supplier ranking¹¹, 5 company headquarters located in USA, 4 company located in Europe, 3 company located in Japan. American companies now represent less than 18 percent of total worldwide semiconductor consumption, but more than 75 percent of US-owned wafer production capacity. Taiwan's foundry industry holds a global market share of 73%, led by TSMC and UMC. Taiwan is also a world leader in Mask ROMs, IC packaging and IC testing, accounting for 57.1%, 32% and 36% of the global market shares respectively. Outsourcing of design implementation services and manufacturing continues to play an important role. In China, many blindly started wafer production lines focus on foundry services. So in this stage, Taiwan and other Asia economic bodies have absolutely advantage. China's top ten IC companies received 45.2% of China's total IC revenue in 2004, but in

¹⁰ The unit of length, $1\mu\text{m}$ equals 10^{-6}m , it also call "micrometer".

¹¹ IC insight, Company Report, <http://i.compnet.com/siliconstrategies/2006/10/top15.gif>

which test and packaging revenue accounted for over 70% of the total revenue. For logical IC, wafer size and manufacturing techniques determine the production cost. 12-inch and 90nm or 65nm wafer is the lowest-cost solution for logical IC. In logical IC field, wafer foundry fabs in mainland China are all of weak competitiveness except SMIC. 45 out of 57 wafer fabs in mainland China are still manufacturing products over 0.5 μ m. The momentum of the Chinese foundries will continue to weaken as companies struggle with competition and constraints on operational scale and technology competency.

Chart 5 2007 China Fab Trend



Source: www.uscc.gov/hearing/2005hearing/written

There are currently 47 wafer fabrication lines in China, up from 40 in 2005. The number of 8- and 12-inch wafer fabrication lines in China is currently 12, and the mainstream wafer size is still 5-6 inches, with a total of 21 lines. The remaining 14 lines handle 4-inch wafers¹². Two of the seven lines (Chart 5), which were installed in 2006, belong to a joint venture of STMicroelectronics and Hynix Semiconductor. Production value from wafer fabrication lines in China will reach US\$2.03 billion in 2006, more than doubling last year's US\$1 billion.

3.4 Market

China is the biggest IC market, but domestic manufacturers account for a small proportion. The strong growth for semiconductors is driven by a large and fast growing domestic manufacturing industry of information communication technology products and equipment. In 2005, the whole country consumed 23 percent of global semiconductors, but China's homemade IC products accounted for merely 16% of domestic demand in value level; 25 percent domestic market in pieces level. Most chips will have to be imported by electronics equipment manufacturers.

IC products tend to be low and mid-end products. The amount of IC consumed in China by OEMs and electronics manufacturing services (EMS). Of these domestically produced chips, about 50% of local production is exported to meet overseas demand for low-end products. High-end products are few, especially IC products aiming at senior system manufacturers. Actually like many global electronics companies, IBM buys a lot of production materials on bare printed circuit boards, board assemblies,

¹² China Semiconductor Industry Association (CSIA)

chassis, power supplies and thermal management devices, at the same time, buys very few semiconductors in China. "Most electronic components are produced outside of China. Raw wafer and IC technology exists in China, but it is substantially behind production that is available from other regions. There's the lower cost of employing a chip design engineer in Asia, which is typically between 10-and-20 per cent of the cost in Silicon Valley, China's competitiveness are still originates from lower cost.

3.5 Raw material and equipment

In 2005, global semiconductors material revenues get to \$31billion, semiconductor equipment \$33billion, semiconductors \$210 billion, electronic and equipment \$1340billion¹³. With semiconductors material and equipment, basically, the mainstream enterprises are enterprises of developed countries. The U.S. is with prevailing absolute advantages. According to a July 2006 forecast by the Semiconductor Equipment and Materials Institute (SEMI), the semiconductor-equipment market in China is expected to reach US\$2.37 billion that year. There were conducted with 15 equipment manufacturers in China. Related raw material also restricts Chinese IC industry.

In sum, China IC industry has had a big scale, and entered a rapid growth stage. Compared with multinational corporations, local enterprises in China's capital, technology and R & D, etc., are at a distinct disadvantage. This does not mean that Chinese enterprises would lose all the opportunities. The world situation is undergoing profound changes in the IC industry. Offshore production and outsourcing contracts have become a trend. Chinese enterprises should select starting point and accelerate the upgrading of its core competencies.

4. INDUSTRIAL UPGRADING STRATEGY AND APPROACHES

Will China be able to move beyond its current status of a low-cost export-oriented global factory and upgrading IC industry through GVC? There are some basic approaches:

Clustering: As both process technologies and design capabilities are tacit knowledge, proximity provides the opportunity for them to reinforce each other and to create synergy. China's electronic manufacturing industry ecosystem concluded that leading EMS companies from abroad, international OEM/OBMs, Taiwanese ODMs, and China's domestic top 100 electronic enterprises are clustered mainly in China's nine major eastern coastal cities/provinces. In IC industry, China government have designated 7 national clusters bases, should further clustering all of recourses in the base, strengthen the inter-firm and institute linkage. National Semiconductor, Solectron, Fairchild, and AMD have all moved into Suzhou. To continue attracting FDI and MNCs investing in China, at the same, the government should attract overseas Chinese talents return back to the motherland.

Standardizing: The overall objective of the strategy for China's technical standards should be capable of supporting Chinese enterprises and products in entering the international market and ensuring the superiority of China's key industries in international competition. TD-SCDMA competes with European-backed 3G standard WCDMA (wideband CDMA) and US-backed CDMA 2000 and is the only one of the three systems yet to be deployed commercially. The proposed issuing of 3G licenses will bring new opportunities in the telecommunications sector. So the government and China LICs should grasp the historical opportunity to develop national Semiconductor industry.

Innovating As an upstream node of the IC industry supply chain, IC design is recognized as the dragonhead of the entire IC supply chain. The real core technologies cannot be purchased but can only be achieved by innovation, particular in the IC industry. In 2003, Taiwanese firms were granted 6,676

¹³ SEMI, SIA, Henderson Ventures January 2006

patents by the U.S. patent office, making Taiwan the fourth-ranked patent receiver (Chen, 2005). In the case of HSP, linkages to the major markets are achieved by its innovation of a new business model whereby Taiwanese IC firms provide foundry service to the world's integrated device makers (IDM) and fables¹⁴ design houses. The government and firms should enlarge the R&D investment in the chip design and related industry.

Emphasizing IC design houses are divided into 6 categories: fundamental IC design houses, multimedia IC design houses, communications IC design houses, smart card IC design houses, PC peripheral IC design houses and others. Media Tek is the worldwide largest DVD player and IC manufacturer with a stable capacity of 50,000 --- 60,000 pieces per month. For China, IC industry has taken some advantages in MP3, multimedia and so on, but in DVD industry, all of manufacturers are controlled by Media Tek and IC companies. The China IC industry should focus on some areas and fulfill breakthrough at first.

Educating China high-level workforces are in short supply, especially in technical, management and marketing personnel. By 2010, China will need around 250,000 IC designers. More educated and skilled work force in and around LICs, have lured more multinationals to subcontract higher-value manufacturing to local companies, to source more parts and components locally, and to set up more producer service and R&D functions in LIC.

However, led by government policies, it is forecasted that by 2010 China will foster 20-30 IC design houses with over US 100 million annual output value, including 2-3 large IC design houses of over US 1 billion annual output value. Meanwhile, the total output value of domestic IC design industry will reach about RMB 50 billion, and the design technology will be 65nm.

REFERENCES

- Gereffi, G.J. H.& Timothy, S. 2005. The governance of global value chains. *Review of International Political Economy*. 12(1):78-104.
- Gereffi, G. 2005. New offshoring of jobs and global development, International institute for Labour Studies, International Labour Office Geneva, ILO Social Policy Lectures, Jamaica, December.
- Gereffi, G. 2006. Development models and industrial upgrading in China and Mexico: the role of international trade and foreign direct investment, presented at the workshop on "Foreign Direct Investment and Economic Development in Comparative Perspective," DUKE University, April 8-9.
- Gereffi, G. O. M. 2003. *The Global Apparel Value Chain: What Prospects for Upgrading by Developing Countries?* UNIDO, Vienna.
- Porter, M. E. 1990. *The Competitive Advantage of Nations*. New York: The Free Press.
- Porter, M. E. 2001. Cluster Innovation: Regional Foundations of U.S. Competitiveness. Council of Competitiveness, Washington, D.C.

¹⁴ A fables semiconductor company specializes in the design and sale of hardware devices implemented on semiconductor chips. It achieves an advantage by outsourcing the fabrication of the devices to a specialized semiconductor manufacturer called a semiconductor foundry or "fab."